FIELD TESTING NEAR-IR AND NEUTRON SPECTROMETER PROSPECTING: APPLICATIONS TO RESOURCE PROSPECTOR ON THE MOON.

R. C. Elphic[1], A. Colaprete[1], J. L. Heldmann[1], M. C. Deans[1], and the MVP Science, Data System and Rover Operations Teams, [1]NASA Ames Research Center, Moffett Field, CA 94035

Introduction: While we know there are volatiles sequestered at the poles of the Moon [1,2], the detailed 3-D distribution, abundance, and physical and chemical form are largely unknown. The next giant leap, Resource Prospector (RP), will use landed assets to fully characterize the volatile composition and distribution at scales of tens to hundreds of meters. To achieve this range of scales, mobility is required. Near realtime operation of surface assets is desirable, with a concept of operations very different from that of rovers on Mars. For RP, new operational approaches are required to carry out real-time robotic exploration.

The Mojave Volatiles Project (MVP) is a Moon-Mars Analog Mission Activities (MMAMA) program effort aimed at (1) determining effective approaches to operating a realtime but short-duration lunar surface robotic mission, and (2) performing prospecting science in a natural setting, as a test of these approaches. Here we describe some results from the first such test, carried out in the Mojave Desert between 16 and 24 October, 2014. The test site was an alluvial fan just E of the Soda Mountains, SW of Baker, California. This site contains desert pavements, ranging from the late Pleistocene to early-Holocene in age, as shown in Figure 1. These pavements are dissected by the ongoing

Fig. 1. The MVP field site in the E Soda Mountains area of the Mojave Desert. Outlines denote areas containing strategic and tactical objectives. Rover Start Pt: 35.180720°, -116.190414°.

development of washes. A principal objective was to determine the hydration state of different types of desert pavement and bare ground features [3]. The mobility element of the test was the KREX-2 rover, designed and operated by the Intelligent Robotics Group at NASA Ames Research Center. The MVP project was described by [4].

MVP Field Test Setup and Instruments: The MVP field test required distributed operations: the Ames Science Operations Center (ASOC) at Moffett Field was responsible for assessment of realtime telemetry, traverse planning, and overall operational management; the Mojave Remote Operations Center (MROC) was responsible for rover operations, instrument configuration management, telemetry flow to the ASOC, and traverse plan execution.

KREX-2 hosted several instruments: stereo cameras and a lidar for navigation and hazard assessment, a

Fig. 2. KREX-2 rover traversing desert pavements and nearby features during the MVP test. The neutron spectrometer is mounted between the two wheels on the right.

downward-looking camera to characterize the pavement and/or bare ground type, and two instruments from the RESOLVE payload on Resource Prospector: the near-IR volatile spectrometer system (NIRVSS) for assessing surficial hydration and mineral mixtures, and the neutron spectrometer system (NSS) to gauge volumetric hydration and elemental composition variations within the top 30 cm. A ^{252}Cf neutron source was used to interrogate the surface materials (needed only in terrestrial settings). KREX-2 is shown in operation in Figure 2.

Mission Operations: Planning was carried out in two steps: strategic plans were created that identified broad areas of different pavement types and nearby features, while tactical plans were constructed within the strategic planning areas to achieve specific way-

points within the pavements, bare ground areas and washes. The strategic planning areas are shown in cyan in Figure 1, focused on areas of dark-, medium- and light-toned desert pavements. Tactical traverse plans were created to explore features within each of the strategic zones. These tactical traverse plans were uploaded for execution by the rover.

Initial Results for Prospecting: NSS measured the neutron albedo at thermal and epithermal energies. Assuming uniform geochemistry and material bulk density, hydrogen as H_2O/OH in mineral assemblages or as soil moisture significantly enhances the return of thermalized neutrons. NIRVSS measures OH, H_2O and other surficial mineralogic spectral reflectance features in the near-infrared.

Figure 3 shows some results of NIRVSS and NSS prospecting during the MVP test. It can be clearly seen that for lighter toned materials (bar and swale, and wash materials) NIRVSS indicates a higher surficial hydration state than the dark pavements. In contrast, thermalized neutron flux is lower in these features, indicating a reduced volumetric H_2O/OH content. In the mature, darker pavements with the greatest desert varnish, higher thermal neutron fluxes are found, indicating greater volumetric hydration. Here, NIRVSS indicates a lower surficial hydration.

This apparent inconsistency between the two results actually illustrates the strength of operating the two approaches to prospecting, and has a relatively straightforward explanation. The dark pavements are composed of clasts of desert-varnished rock, consisting of largely anhydrous mineralogy – they appear surficially dry. However, these 2-3 cm thick pavement surfaces are underlain by a clay-rich layer unseen by NIRVSS, the Av1 horizon, in which enhanced OH and H_2O are present in clay minerals such as illite and chlorite. Within the light-toned washes, clay-bearing materials are also present and observable by NIRVSS – but volumetrically their abundance is lower than under the dark pavements, and so appear “drier” to NSS.

We will discuss these results and how the NIRVSS and NSS prospecting instruments will be used as part of a real-time decision support system on Resource Prospector.

References: [1] Feldman W. C. et al. (1998) *Science*, *281*, 1496. [2] Colaprete, A. et al., (2010) *Science, 330,* 463, DOI: 10.1126/science.1186986. [3] Wood, Y. A. et al. (2005) *CATENA, 59,* 205, DOI: 10.1016/j.catena. 2004.06.001. [4] Heldmann, J. L., et al., (2014) *AGU Fall Meeting,* Abstract P11D-05.

Acknowledgements: This work was supported by the SMD “Moon and Mars Analog Mission Activities” Program (MMAMA). NSS and NIRVSS instruments were developed under HEOMD Advanced Exploration Systems. The MVP Science Team included: B. Cohen, S. Karunitillake, J. R. Skok, A. Cook, M. Marinova, K. Ennico, and D. Lim. The rover operations, field support and xGDS teams included M. Allan, V. To, R. Gogni, L. Kobayashi, L. Flückiger, M. Furlong, M. Dille, J. Gin, D. Lees, T. Cohen, T. Smith. Rusty Hunt served as flight director.

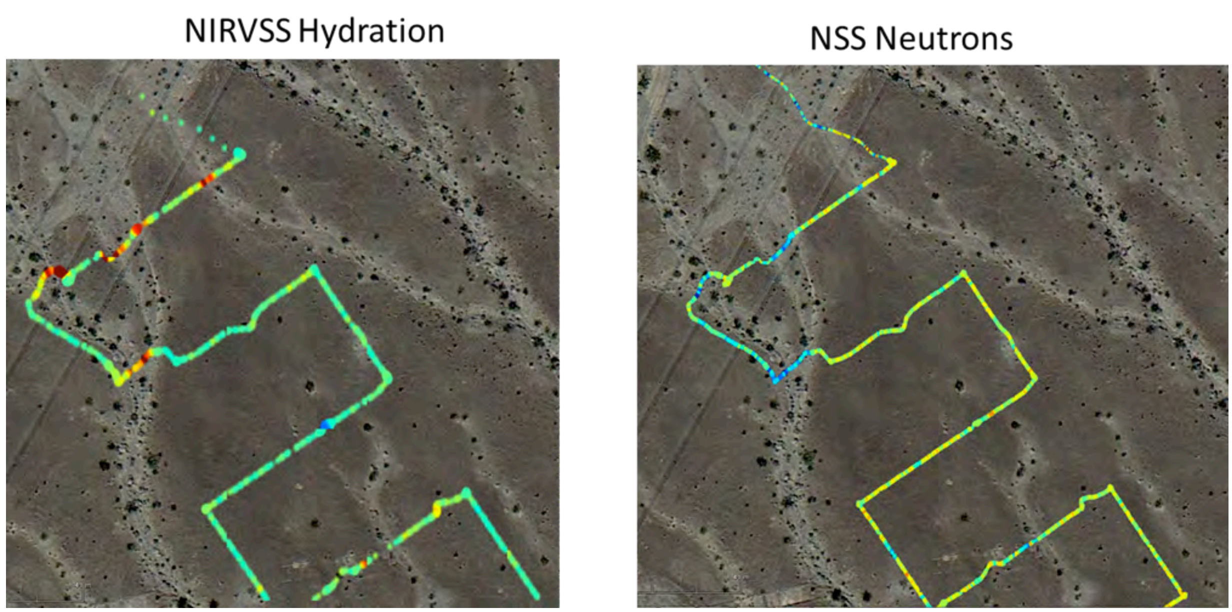

Fig. 3. xGDS raster maps showing (left) NIRVSS spectral product indicating surface hydration (hydrous minerals or surface-adsorbed H_2O), and (right) NSS thermalized neutron count rates for a portion of a traverse across dark desert pavements dissected by washes. Hotter colors in the NIRVSS map denote higher hydration – essentially band depth due to H_2O/OH absorption near 2 μm wavelength. Higher count rates (warmer colors) denote greater hydrogen abundance in the top 30 cm of surface